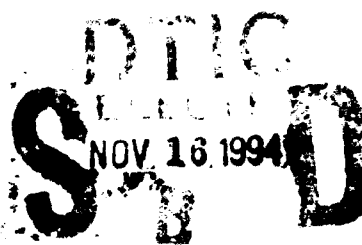AL/CF-TR-1994-0074

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SYSTEMS ENGINEERING DESIGN AND TECHNICAL
ANALYSIS FOR STRATEGIC AVIONICS CREW STATION
DESIGN EVALUATION FACILITY (SACDEF) (U)

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FINAL REPORT FOR THE PERIOD 15 JANUARY 1988 TO 14 MAY 1993

AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-7022

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ARMSTRONG LABORATORY

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AL/CF-TR 1994-0074

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

KENNETH R. BOFF, Chief
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13. ABSTRACT (Maximum 200 words)

This report summarizes all work efforts completed under Contract F33615-87-C-0531, SEDATA for SACDEF. This report consists of four main sections. Section 1 is an overview of SACDEF contract. Section 2 contains descriptions of specific tasks completed under the SEDATA for SACDEF contract. Section 3 contains conclusions and recommendations. Section 4 contains references, which includes reports and documentation produced under specific tasks of the contract.

The Armstrong Laboratory has been involved in supporting the development and refinement of Strategic Bomber Crew Systems for almost 25 years. The SACDEF of the CFHI branch within the Human Engineering Division is responsible for research addressing crewstation design and areas currently include aircrew workload evaluations, new control/display concepts, display device image quality, and electro-physiological correlates of crew performance. Specific emphasis is directed toward the development of advanced controls and displays for bomber aircraft, employing state-of-the-art, multifunctional display devices and computer programming techniques. An ongoing requirement has been to maintain the SACDEF B-52G Defensive Simulator and the B-1B Engineering Research Simulator (ERS) as designed, developed, tested, and delivered to Armstrong Laboratory under a previous contract. This report documents the work activities completed by Science Applications International Corporation for the SEDATA for SACDEF over the period 15 January 88 through 14 May 1993.

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SUMMARY

The Armstrong Laboratory has been involved in supporting the development and refinement of Strategic Bomber Crew Systems for almost twenty-five years. The Strategic Avionics Crew Station Design Evaluation Facility (SACDEF) of the Crew Systems Integration Branch (CFHI) within the Human Engineering Division, is responsible for research addressing crew station design and aircrew workload for current and future strategic aircraft. The functional research areas currently include aircrew workload evaluations, new control/display concepts, display device image quality, and electro-physiological correlates of crew performance. Specific emphasis is directed toward the development of advanced controls and displays for bomber aircraft, employing state-of-the-art, multifunctional display devices and computer programming techniques. An ongoing requirement has been to maintain the SACDEF B-52G Defensive Simulator and the B-1B Engineering Research Simulator (ERS) as designed, developed, tested, and delivered to Armstrong Laboratory under a previous contract. This report documents the work activities completed by Science Applications International Corporation (SAIC) for the Systems Engineering Design and Technical Analysis (SEDATA) for SACDEF, under Contract F33615-87-C-0531 over the period 15 January 1988 through 14 May 1993. Emphasis is placed on a summary description of the specific tasks completed under the contract.

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PREFACE

This document provides a summary final report covering all work efforts completed under Contract F33615-87-C-0531 issued to Science Applications International Corporation (SAIC) by the Air Force Systems Command, Armstrong Laboratory (AL). All contracted efforts for the first three years of the five-year contract were monitored and directed by Lt Col William Marshak. For the last two years of the contract, all contracted efforts were monitored and directed by Lt Col Michael Eller. The specific tasks and projects reported herein, in many cases, have separate, more detailed reports of the results. Where applicable, the reports are cited in the text and are included in the References Section of the report.

This report consists of four sections. Section 1 is an overview of SACDEF and the Systems Engineering Design and Technical Analysis (SEDATA) Contract. Section 2 is a description of specific tasks completed under the SACDEF SEDATA contract. Section 3 is Conclusions and Recommendations. Section 4 is References.

During the first two years of the contract (15 January 1988 - 1 December 1989), Mr. Robert Prior was the SAIC Program Manager for the contract. During the period of 1 December 1989 through 14 May 1993, Mr. John Stengel was the SAIC Program Manager. The Aeronautical Systems Operation of SAIC (Dayton, Ohio) was the principal performing organization for contracted activities. Other SAIC offices were used throughout the course of the contract on an as-needed basis to ensure proper experience and expertise were brought to bear on each particular task assigned. As such, there are multiple SAIC contributors to the work reported herein. The principal writers for this report were Mr. John Stengel, Mr. Harry Heaton, Mr. Steve Finch, Mr. James Hopper, Ms. Teresa McKelvey, Mr. Dan Blazer, Mr. Roger Overdorf, Mr. Steve Rizzi, Mr. Tom Zawodny, Ms. Carol Mathews, Dr. Gregg Irvin, Ms. Janet Irvin, Mr. Harold Dean, and Mr. Gene Welch.

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SECTION 1

OVERVIEW OF THE SYSTEMS ENGINEERING DESIGN AND TECHNICAL ANALYSIS (SEDATA) FOR THE STRATEGIC AVIONICS CREW STATION DESIGN EVALUATION FACILITY (SACDEF)

1.1 OVERVIEW OF THE SACDEF

The Human Engineering Division of the Armstrong Laboratory (AL/CFH) is responsible for the exploratory and advanced development of Man/Machine Integration Technology. Areas of research interest include: (1) developing information about the perceptual, cognitive, and response characteristics of human operators; (2) developing methods and principles which will permit translation of such information into new concepts for control and display; and (3) developing standardized methodologies for assessing the improvement in system performance due to man-machine interface changes. The Strategic Avionics Crew Station Design Evaluation Facility (SACDEF), of the Crew Systems Integration Branch (AL/CFHI) within the Human Engineering Division, is responsible for research addressing crew station design and aircrew workload for current and future strategic aircraft. The functional research areas currently under SACDEF investigation in support of the AL/CFHI mission include aircrew workload evaluations, new control/display concepts, display device image-quality, and electro-physiological correlates of crew performance. Specific emphasis is being directed toward the development of advanced controls and displays for bomber aircraft, employing state-of-the-art, multifunctional display devices and computer programming techniques.

Over the past twenty-five years, SACDEF has been tasked to support evaluations of avionics improvements in current and future strategic aircraft. These human factors engineering evaluations of the avionics suite and crew station design have been typically performed using Strategic Air Command combat ready crews in real-time, simulated missions.

The Crew Systems Integration Branch meets its research objectives, to a large degree, by means of experimentation in its on-site laboratory facility. The SACDEF facility consists of highly specialized, state-of-the-art simulation and human performance assessment capabilities, driven by real-time computers employing specially developed, one-of-a-kind software packages. An ongoing requirement exists to maintain the SACDEF B-52G Defensive Simulator and the B-1B Engineering Research Simulator (ERS), and to integrate into SACDEF future strategic bomber simulators, as necessary, to support human engineering/workload assessment studies.

1.2   THE SACDEF SEDATA CONTRACT

The purpose of the SACDEF SEDATA Contract was to provide the professional, scientific, engineering and technical support, materials, equipment, and supplies required to: (1) obtain, operate, maintain, modify, and develop simulators and other systems required by SACDEF; and (2) conduct advanced human engineering studies and workload assessment evaluations. Program management functions were an integral part of all contract activities.

Areas of research included: (1) aircrew performance assessments within flight simulators; (2) development of advanced strategic crew station integration concepts; (3) development of cockpit automation techniques for strategic aircraft, including the application of artificial intelligence concepts; (4) utilization of behavioral and physiological workload metrics/performance assessment techniques and subjective workload assessment techniques; (5) advanced display image quality analysis ar 1 control suitability; and (6) assessment of perceptual and cognitive crew loading factors.

Software support included: (1) real-time programming techniques for aircraft simulation; (2) development of mission software (including appropriate data bases); (3) mathematics associated with flight simulation, including modern control theory; (4) math modeling techniques; (5) numerical methods, data reduction, and statistical analysis; (6) principles of image processing and transformation; (7) real-time interactive graphics systems programming; (8) operating systems software; (9) artificial intelligence concepts; and (10) microprocessor development and software development for highly specialized computer interfaces.

Human engineering studies were typically performed on specialized research simulators located at Wright-Patterson AFB (WPAFB), Bldg. 248, or the B-1B flight, offensive, and defensive crew station simulators, which for three and one half years of the contract were located at Grand Forks AFB, North Dakota and Ellsworth AFB, South Dakota. Experimental studies and analysis support included assistance in the collection of data for human engineering, operator performance, and man-machine simulation experiments.

Daily operation and maintenance (O&M) of all equipment in the SACDEF facility was completed for the entire duration of the contract. Daily operation and maintenance was also required for the three and one half years the Engineering Research Simulators (ERS) were deployed at Grand Forks AFB, ND and Ellsworth AFB, SD. The O&M activities for the ERS were also supported by Lear Siegler International (LSI) under subcontract to SAIC for the three and one half years of deployment.

Program management activities were conducted over the duration of the contract. These activities included technical oversight and cost/schedule tracking. Cost reporting and technical status reporting, as required by the contract data

requirements list, were also accomplished as part of the program management activity. Individual principal investigators were responsible for providing information on their particular task(s) activities. The overall contract program management activities were accomplished by the SACDEF Program Manager.

The contract activities summarized above were characteristically far more detailed in nature than one might conclude from the brief descriptions provided. Section 2 of this report contains detailed descriptions of specific tasks completed under the contract on a task by task basis, thus giving additional insight into the details of the actual work.

SECTION 2
DESCRIPTION OF SPECIFIC TASKS COMPLETED UNDER THE SACDEF SEDATA CONTRACT

2.1   INTRODUCTION

The following paragraphs describe the specific tasks completed under the SACDEF Systems Engineering Design and Technical Analysis Contract. Each task is presented by task assignment number and title. A brief description of the objective/purpose of each task is also identified. Summary results for each task are presented. For the purpose of this report, summary results are, of necessity, brief when compared to the magnitude of the work activities conducted. Specific detailed results were, in many cases, separately documented. Also listed are the principal investigator(s) from SAIC and the Air Force Monitor responsible for each task. The tasks are presented in numerical order.

Although not specifically called out as a separate task, program management responsibilities were required. SAIC provided oversight and exercised administrative and financial management control of the overall SACDEF Program, task activities, and operations during the course of the F33615-87-C-0531 Contract. Included in this function were contract administration; the coordination and scheduling of activities and milestones; describing status; outlining contracting activity and progress toward accomplishment of objectives; forecasting and making recommendations on funding and funding changes; program planning; describing in detail the overall results of the effort; and documenting any new technological breakthrough. These activities, as well as all active task activities, were reported on a monthly basis as required by the contract data requirements list.

2.2   SPECIFIC TASKS

2.2.1   TASK 87-0001A-D   ENGINEERING RESEARCH SIMULATOR SUPPORT

AF OPR: Mr. Tom Green
SAIC PI: Mr. Robert Prior

Task Objective:

The task objective was to provide for the operation and maintenance of the B-1B Engineering Research Simulators (ERS) at specified B-1B Main Operating Bases; develop and implement an Integrated Support Plan (ISP) to accommodate the deployment of the B-1B Engineering Research Simulator at Ellsworth, Grand Forks, and McConnell AFBs. ISP requirements to be addressed included support equipment requirements, spares and parts provisioning, management, reporting

methodology, technical data, training, transportation, packaging and storage. Provisions for a software update to track aircraft software releases were to be included.

Task Summary Results:

Deployment of the ERS was accomplished to Ellsworth and Grand Forks AFBs by March 1988. SAIC and LSI staff were relocated to support the operations and maintenance of the ERS. The decision was made in August 1988 to not deploy an ERS to McConnell AFB. Availability of the ERS at both locations averaged over 98% throughout the task. During the conduct of this task, the B-1B ERS provided reliable, high fidelity training to B-1B crew members and helped contribute to the overall readiness of our strategic deterrent force. Accomplishments during this task included supporting several studies: Radar Warning Receiver Study; Flight Director Study; and Auto Map Cuing Study. In addition, an upgrade to the Concurrent Computer operating system was accomplished to achieve greater compatibility between the ERS and High Fidelity Defensive Crew Station Simulator (HFDCS) software. Activities continued under the follow-on task, Task 90-0001.

2.2.2 TASK 88-0001 LOCAL OPERATIONS AND MAINTENANCE

AF OPR: Mr. Tom Green
SAIC PI: Mr. Robert Prior

Task Objective:

The task objective was to provide for general operations and maintenance support of SACDEF facilities and associated hardware and software elements to include the B-1B High Fidelity Defensive Crewstation Simulator (HFDCS), B-52G Defensive Station Simulator (DSS) and Instructor's Console, Programmable Display Generation System (PDGS), and Color Display Generation System (CDGS).

Task Summary Results:

Support activities consisted of integrating the B-1B Engineering Research Simulator (ERS) Hotbench Offensive hardware into the HFDCS; development of a Night Vision Goggle (NVG) lighting mock-up using surplus B-52 flight station simulator assets; and technician support for ERS Contractor Logistics Support (CLS), Aim Sight, HFDCS, Color Study, B-1B Radar Warning Receiver (RWR), B-1B Central Integrated Test System (CITS), and B-52 DSS Upgrade activities. In addition, general support to AL and the SACDEF facility was provided on an as-required basis. Continued support was accomplished under the follow-on task, Task 89-0006.

2.2.3   TASK 88-0002   HIGH RESOLUTION DIGITAL DATA OPTIMIZATION STUDY SUPPORT

AF OPR: Major Michael Sieverding (now retired)
SAIC PI: Mr. Robert Prior

Task Objective:

This task was the second phase of the High Resolution Digital Data Optimization Study. The first phase of this study was conducted under the previous SACDEF Contract. This study was sponsored by the Aeronautical Systems Division Training Systems Program Office (ASD/YW) and was a multi-agency activity. Principal participants included ASD/YW, the Air Force Human Resources Laboratory (AFHRL/OTE), Headquarters Strategic Air Command (SAC/DOTPX), 338th Bombardment Wing (BMW), 285 BMW, 319th BMW, General Electric, and the SACDEF Team (AL/CFHI and SAIC). This study was designed to permit comparison and evaluation of aircrew performance measures (e.g., time and accuracy) between real synthetic aperture radar (SAR) imagery and different versions of synthetically generated imagery

Task Summary Results:

SAIC integrated high resolution data bases on the B-1B ERS created by General Electric Corporation from a number of prototype Defense Mapping Agency digital products. Subject testing was done on-site from 1 to 6 June 1988 at Ellsworth AFB and from 8 to 10 June at Grand Forks AFB. The study compared and evaluated aircrew performance measures (e.g., decision time and accuracy) between real SAR imagery and different versions of synthetically generated imagery. The synthetic imagery was provided from three levels of Digital Feature Analysis Data (DFAD) reflecting various data densities and alternative data generation methodologies. The source of SAR imagery used was actual B-1B radar data, generated on the BAC 1-11 test bed aircraft and acquired from Westinghouse during Phase I of the study. All synthetic imagery was provided as Government-Furnished Equipment (GFE) by AFHRL/OTE. The original plan was for 41 subjects (provided by 28th BMW at Ellsworth AFB and the 319th BMW at Grand Forks AFB). However, due to schedule conflicts of the subjects, only 34 were actually available for the testing. It was determined, however, that an ample quantity of data was obtained to support a meaningful and valid analysis. Results of the study were instrumental in defining requirements for new Defense Mapping Agency digital cartographic products for training applications.

2.2.4   TASK 88-0003   AFSATCOM SYSTEM INTEGRATION

AF OPR: Mr. Earl Sharp
SAIC PI: Mr. Harold Dean

Task Objective:

The Air Force Satellite Communications System (AFSATCOM) communication system is used in strategic aircraft to provide a secure communication link for code transmissions. The objective of this task, the second of a planned two-phase integration approach, was to provide hardware and software modifications to the B-1B HFDCS necessary to integrate the AFSATCOM special input/output (I/O) device developed in Phase I into the HFDCS simulation.

Task Summary Results:

Software modifications to the AFSATCOM interface board were completed as required. This enabled the AFSATCOM special I/O to be integrated into the B-1B HFDCS. Specific activities associated with this task included modifications to the HFDCS linkage unit software in order to support integration; and development of interface modules. Based on a set of common requirements shared by the B-1B ERS and the HFDCS, it was decided to complete the development of a printed circuit board as part of the HFDCS support task (Task 88-0004). An AFSATCOM demonstration was subsequently provided to Mr. Sharp to complete all task requirements.

2.2.5   TASK 88-0004   B-1B HIGH FIDELITY DEFENSIVE
CREWSTATION SIMULATOR (HFDCS)

AF OPR: Mr. Earl Sharp
SAIC PI: Mr. Robert Prior/Mr. Steve Finch

Task Objective:

The B-1B High Fidelity Defensive Crewstation Simulator (HFDCS) is an advanced version B-1B Engineering Research Simulator (ERS) Defensive crewstation, with fidelity and functionality improvements added to enhance realism and to more accurately emulate the B-1B's Defensive Systems Operator (DSO) man and machine interface. The objective of this task was to continue the process of improving the B-1B HFDCS capabilities, by maintaining currency with the aircraft, and implementing software and hardware modifications to support continuing research.

Task Summary Results:

Activities accomplished for this task included: CITS software integration (with simulated malfunctions); new integrated baseline (CITS, AFSATCOM, B-1B Offensive Systems Operator (OSO) Screens, improved audio synthesis) and initial audio spectral analysis. In addition, considerable strategy development and planning for the ALR-56M Radar Warning Receiver (RWR) Integration Study in support of Boeing, AL, and ASD were accomplished. The RWR study was accomplished during December 1989.

In preparation for the RWR study, basic updates to the HFDCS were identified including multi-function display (MFD) interface error; the need for an experimenter station and data collection; and the need for tools to laydown threats, modify the threat library, and provide verifiable threat identification (ID) processing. In addition, the need for an interface to the Emitter Identification (EID) in order to perform real-time ID processing was identified. Due to the fact that there is a basic defensive station commonality other than Electronics Display Unit (EDU) software between HFDCS and the ERS, scheduled ERS upgrades to Avionics Flight Software (AFS) Version 4.5 were shared with the HFDCS.

Specific upgrades to the HFDCS included correction of an MFD interface error which resulted in a major upgrade to the defensive station software; development of a battle management screen and integration into the HFDCS; development of tools to check the loading process of the threat data bases; and upgrade to the threat library. In addition, data collection software and an experimenter station were developed for the study. Extensive software upgrades and developments kept the human factors analysis to a minimum.

Three variants were developed for the RWR Study. The baseline included implementation corrections, the Battle Management MFD Screen from AFS 4.5 Merge 3, and ALQ-161A Core Goals. The RWR Standalone formed the baseline with the RWR display above the EDUs. The third study involved the RWR integrated with RWR data integrated into the EDU displays and Battle Management Screen.

Results of the study indicated that the RWR standalone and RWR integrated modes on the EDU improved defensive operator performance and reduced aircraft visibility to threats compared to the baseline RWR software architecture. Although the RWR integrated mode provided only slightly better visibility results in comparison to the RWR standalone mode, it did provide a substantially better control and display interface. Briefings were given to Boeing and Rockwell and a technical report was completed and delivered.

2.2.6 TASK 88-0006 ANALOG HELMET MOUNTED DISPLAY ELECTRONIC (AHMDE) SOFTWARE DEVELOPMENT

AF OPR: Mr. Alan Straub
SAIC PI: Mr. Jim Hopper

Task Objective:

The objective of this task was to specify, design, and implement the embedded software for the Analog Helmet Mounted Display Electronics (AHMDE) subsystem of the Virtual Panoramic Display (VPD) system. Specific requirements included the development of functional requirements for the AHMDE, design and implemention of the software, and hardware/software integration. In addition, requirements analysis and trade studies to identify hardware and software requirements to support the AHMDE subsystem development and maintenance were required.

Task Summary Results:

Activities accomplished for this task included: design and implementation of the AHMDE control and initialization software; specification of requirements for the AHMDE executive; integration and testing of lower level drivers to run the Verdix debugger; and software integration and testing of the initialization software. Software and hardware integration was delayed due to the hardware delivery delay from Electronic Imagery Systems (EIS). Redirection of task activities and personnel by the Air Force, in addition to problems encountered with GFE hardware, resulted in funds not being available to finish activities under this task. Additional activities were completed under Task 88-00011R1, as well as under subcontract to Logicon Technical Services Incorporated (LTSI).

2.2.7 TASK 88-0007 PHASE II COLOR RESEARCH PROTOCOL DEVELOPMENT

AF OPR: Ms. Denise Wilson
SAIC PI: Dr. Gregg Irvin

Task Objective:

The task objective was to provide input to the Air Force regarding the utility of color coding defensive crewstation displays. By taking a problem-oriented approach to improving Defensive Systems Officer's (DSO's) performance, the goal of the initial Phase II effort was to investigate DSO operational problems and define the appropriate use of color to solve them.

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Task Summary Results:

Activities accomplished for this task included: the development of a high workload mission scenario for task analysis validation; the development of a DSO task analysis questionnaire; DSO task analysis completed at Dyess AFB; and facility design requirements for conducting DSO color studies. After determination of equipment needs, software for programming the Sperry Color Display Generation System (CDGS) computers was developed. Several DSO operational problems were solved including the track handle interface and the installation of the Stroke And Raster Graphics Environment (SARGE) system on the MicroVAX computer system.

In addition, a significant amount of effort was dedicated to reverse engineering and correcting hardware problems with the CDGS. Performance problems believed to be associated with the CDGS/VAX system interface and associated GFE software precluded completion of data collection.

2.2.8   TASK 88-0008   AIM SIGHT PHASE I DEVELOPMENT

AF OPR: Lt Col William Marshak
SAIC PI: Mr. Dan Blazer/Ms. Teresa McKelvey

Task Objective:

The task objective was to develop a full mission simulation capability for prototyping, testing, and evaluating crew station improvements for existing bomber aircraft, using components which are deployable using today's technology. The scope of these improvements could include helmet-mounted heads-up displays, helmet-mounted sights, Forward-Looking Infrared (FLIR) imaging systems, and night vision systems. SAIC was tasked to demonstrate the capability of the man-machine interface (MMI) concepts in the Visually-Coupled Airborne Systems Simulator (VCASS) laboratory utilizing the flight dynamics provided by the VCASS. Additionally, SAIC was required to provide a standalone capability with the HMD with the heads-up displays and FLIR imagery in the B-1B ERS to include cuing capability between the crewmember positions.

Task Summary Results:

Activities accomplished for this task included: development of an Imaging Sensor Simulation; preparation, conduct, data reduction, and analyses and demonstration of an Imaging Sensor Simulation study; development and integration of Helmet Mounted Displays with VCASS and with the AN-AAQ-17 FLIR located in the Avionics lab; development of an interactive FLIR simulation; and completion of a standalone capability with the heads-up display and FLIR imagery. In addition, a hardware/software architecture was developed for the Aim Sight controller. An MMI for the Aim Sight controller executive software was designed and successfully demonstrated.

2.2.9   TASK 88-0009   NEURAL NETWORK

    AF OPR: Lt Col Paul Morton
    SAIC PI: Mr. Harry Heaton

Task Objective:

The task objective was to support AL/CFHI in the evaluation of the applicability of artificial neural systems (ANS) to the automated evaluation of pilot workload using performance measures. Key elements of the task included: the identification of past related work in the ANS area; evaluation of the suitability of various ANS architectures; an assessment of the B-1B ERS as a test device for an ANS workload evaluation study; and the specification, at a functional level, of an ANS hardware/software system to perform futu: workload analysis.

Task Summary Results:

Meeting the objectives of this task required a brief but wide ranging review of relevant literature. A commercial data base of neural network papers and publications (Neural Base™) was purchased to support the identification of promising neural network architectures. Upon review of the identified literature, it was readily apparent that the application of neural networks to workload analysis was a novel undertaking.

Among the many possible network architectures, several candidate architectures were identified for further evaluation: Kohonen feature maps; counter-propagation, Adaptive Resonance Theory (gray scale); paleocortex simulation; and multi-layer back propagation. It must be noted that considerable variation is possible within any of the architectures, and that the goal of this effort was a proof of concept, rather than an optimization. In essence, any of the architectures is limited to one of two functions: clustering of data or pattern recognition.

Obtaining a data set for candidate architecture evaluation proved a more protracted effort than expected. Although the B-1B ERS was evaluated as a suitable platform for the collection of data, the limited scope of this task required data collection with another Air Force task that utilized the ERS. While awaiting the beginning of the Auto-Map Cuing task, an outside data source was identified. McDonnell-Douglas, in cooperation with National Aeronautics and Space Administration (NASA), had collected an extensive amount of data on the landing performance of pilots using a helmet-mounted display. This data set was made available to AL.

The data set was collected from a series of touch-and-go landings made with an instrumented Boeing-737. The landings were made under three sets of conditions: visual approach and landings made in the usual manner; visual

approach and landings using a helmet mounted binocular display and bore-sighted fixed cameras; and visual approach and landings made using the helmet mounted binocular display and head-slaved cameras.

Due to resource limitations, only the back-propagation algorithm was evaluated. The network was trained to recognize exemplar sets from both normal visual and bore-sighted camera runs of a single pilot. It was assumed that the pilots performance would improve and that workload would decrease over time, so approaches from the middle of the two-week data collection period were selected as training. Both early and late visual and camera runs were then evaluated.

The back-propagation network was successful in categorizing both the early and late runs into the high and low workload states. As expected, more points in the early runs were categorized as high workload, with fewer points assigned to the high workload condition in the late runs, thus a training effect was noted. Also, as expected, more points were assigned to the high workload condition for the fixed camera runs than to the normal visual runs. This agreed with the pilots' subjective Cooper-Harper assessment.

A single head-slaved camera trial was also evaluated. Although a Cooper-Harper rating of this system was not available, it was expected that the assignment of workload condition would more closely resemble that seen for normal visual trials. Instead, nearly all of the points were assigned to the high workload state, more so than for the bore-sighted camera runs.

Although resource limitations prevented an evaluation of additional architectures, the results of the proof-of-concept are encouraging. This is especially true in that the objective evaluation of performance data was in agreement with subjective workload assessments by the subjects. In contrast, conventional assessment of performance, based on touchdown accuracy, found no significant difference between the various visual systems tested.

2.2.10   TASK 88-0010   B-52 DEFENSIVE STATION SIMULATOR UPGRADE

AF OPR: Mr. Earl Sharp
SAIC PI: Mr. Tom Zawodny

Task Objective:

The task objective was to provide proper stimulation of the ALR-46 Radar Warning Receiver (RWR) by the DSS's hardware and software models and to establish and use the ALR-46 RWR's expanded data interface as a realistic input for B-52 Defensive Station Simulator (DSS) Sensor Integration (SI) processing. An additional thrust of this task was to replace the existing Sperry Programmable Display Generation System (PDGS) with a functionally equivalent graphics system.

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Task Summary Results:

Activities accomplished for this task included evaluation of existing B-52 DSS hardware (threat signal generation boards, multiplier boards, and chassis); modifications of the ALR-46 hand-off data interface board; development of alignment procedures for the 155 Jammer system; and development of an alignment system for multiplier boards. Considerable activity for this task involved repair of existing hardware repair and upgrades to the Scan Generation software. As a result, the B-52 DSS was fully operational and capable of supporting crewstation research. In accordance with Air Force direction, the PDGS was not replaced.

2.2.11   TASK 88-0011R1   VIRTUAL PANORAMIC DISPLAY (VPD) ADVANCED ROTOCRAFT VIRTUAL COCKPIT SIMULATOR (ARVCS), PHASE I

AF OPR: Mr. Alan Straub
SAIC PI: Mr. Jim Hopper

Task Objective:

The task objective included providing integration and software development support for the Virtual Panoramic Display (VPD) system. The system was designed and implemented as a prototype, flight worthy, visually coupled cockpit control and display system. Under this task, the following tasks were planned to be accomplished: (1) update VPD system description documents; (2) develop functional requirements for system controller and graphics generator software modules; (3) implement, test, and integrate newly developed VPD software with the AHMDE and MHMS subsystems; and (4) integrate the VPD system into the existing VCASS.

Task Summary Results:

Activities accomplished for this task included: a requirements analysis of VPD controller and graphics generator; requirements and code development for a Heads-up Display: requirements for and development of shared memory; and integration of developed components with the Verdix Ada System. A run-time package for the Verdix Ada system to operate without support from the Verdix debugger was produced. Other activities completed under the task included: development of software to test shared memory as both a standalone and as a modular part of the basic AHMDE software from the control panel; development of software to be used by the Principal Investigator (PI) to access shared memory for the control panel and the Display Head Electronics (DHE); and documentation on configuring Aeroflex processor to the AHMDE system.

2.2.12   TASK 88-0012   AUTOMATIC MAP CUING EVALUATION

AF OPR: Mr. Tom Green
SAIC PI: Mr. Robert Prior

Task Objective:

This task was a joint AL and B-1B System Program Office (ASD/B1) activity to be conducted under the auspices of the March 1988 Memorandum of Agreement between AL/CFHI and ASD/B1. The purpose of this task was to evaluate and assess the effectiveness of the Automatic Map Cuing function which was implemented in the B-1B's Avionics Flight Software Version 4.5. Under this task, SAIC developed and executed a comprehensive study plan, and modified and operated the Engineering Research Simulator (ERS) to support the study.

Task Summary Results:

Activities completed for this task included: an OSO task analysis as well as an evaluation of navigation update tasks including the AMC mode of operation; an experimental design drafted to specify subject requirements, number of test missions, mission duration, mission factors and statistical design for the study; and a basic AMC algorithm integrated and tested on the ERS hotbench and subsequent installation on the Ellsworth AFB ERS as part of the ERS Phase I software update to support the study. Additional activities included evaluation of alternate sources of high resolution synthetic aperture radar (SAR) and subsequent implementation of an SAIC unique synthetic aperture radar simulation approach. Software modifications to the ERS were required to accomplish this activity. Human factors personnel developed a debrief questionnaire to be used as part of the study which was accomplished at Ellsworth AFB. A final report was prepared and delivered to the Air Force.

The results of the study indicate that the AMC feature can aid the OSO under high workload conditions. The analysis of the Subjective Workload Analysis Technique (SWAT) data showed that OSOs reported significantly lower workload for AMC relative to the Manual condition. However, this difference in reported workload was only evident for the weapon delivery test cases that were designed to impose a high degree of workload on the OSOs (threat responses, course deviations, and malfunctions were present). The performance data indicated that subjects in the AMC condition performed more updates and obtained more usable images relative to the Manual group. However, the differences between the two groups in these measures were not statistically significant. The OSOs generally indicated that the controls and displays for AMC were adequate. However, a major objection regarding the placement of the AMC control functions too deeply within the menu structure (FH screen) was raised. For example, a capability to quickly enable/disable the AMC function through a toggle type switch was requested.

Crewmember objections regarding the AMC information display ("NAV C" screen) were attributed to the OSOs' relative unfamiliarity with the AMC feature. The results of the debrief and questionnaire also indicate that AMC can aid the OSO under high workload conditions.

2.2.13 TASK 89-0001 TECHNICAL SUPPORT TO DARPA SRT SCIENCE PROGRAM

AF OPR: Mr. Gil Kuperman
SAIC PI: Mr. Tom Swartz

Task Objective:

The Office of the Secretary of Defense established a steering group to direct Strategic Relocatable Target (SRT) programs. ˙e Defense Advanced Research Projects Agency (DARPA) established an SRT Science Program and AFSC/ASD developed an ongoing SRT Capability Program. AL/CFHI was identified as the associated product division for human factors. The objective of this task was to provide technical support in the evaluation of the observables, sensors, and algorithms to detect, recognize and target SRT target sets: to develop architecture to hold these targets at risk; and to identify technology shortfalls regarding the implementation of the candidate architectures.

Task Summary Results:

Activities accomplished in support of this task included assisting in the generation of a Technology Panel final report. The majority of this effort was editorial. In addition, three generic architectures which included all of the technologies identified in the Technology Roadmap were defined. These architectures were then refined to determine specific technology objectives. In addition, these architectures were used as a basis to define a series of technology demonstrations for the DARPA SRT program. In addition, support was provided to the DARPA program office to assist in the technical review of three proposals and in the preparation of briefings on SRT treaty verification. Technical reviews were also performed regarding the development of a DARPA foliage penetration radar program. With the delivery of an executive summary of the Technology Panel final report, the task activities were successfully completed.

2.2.14 TASK 89-0002 STRATEGIC MISSION ANALYSIS

AF OPR: Mr. Gil Kuperman
SAIC PI: Mr. John Stengel

Task Objective:

The task objective was to provide a detailed route segment description for a strategic bomber mission encompassing target acquisition and strike of mobile targets, perform a utility analysis of a mission decomposition software tool using the developed mission segments, develop measures of effectiveness (MOEs) and measures of performance (MOPs) to support modeling and man-in-the-loop simulation studies, and develop conceptual control and display formats for mobile target acquisition and strike.

Task Summary Results:

This task developed procedures to design conceptual controls and displays to assist a B-1B Offensive Systems Operator with the task of acquiring and striking strategic relocatable targets. Inputs to the overall design process included the specification of strategic relocatable target information, strategic aircraft avionics data, digital and cartographic data, a threat laydown based on the 1988 Strategic Intelligence Future Forecast (STIFF)/Order Of Battle - Defensive (OBD), and an operational concept based on Concept I and Concept II avionics capabilities. Products of the Strategic Mission Analysis Task included an SRT mission scenario, refined mission data including detailed timelines and function flow diagrams, a documented analysis and design process, and a study plan including the specification of appropriate measures necessary for evaluation of controls and displays actually developed. In addition, results and recommendations from the evaluation of a commercial software tool (Merit Technology's Mission Decomposition Tool (MDTool)) intended to help automate the mission development and decomposition process were developed. A series of conceptual controls and displays were also developed. Deliverables provided as a result of this task included a final report documenting all findings and recommendations. A Silicon Graphics 4D/50 workstation, acquired as a part of this task, was also delivered to the Government.

2.2.15   TASK 89-0003   MAN MACHINE INTERFACE DESIGN FOR ELECTRONIC COMBAT (EC) DIGITAL SIMULATIONS

AF OPR: Mr. Earl Sharp
SAIC PI: Mr. Jeff Wise

Task Objective:

The rapid advancement in display technology, along with the growing Air Force demand for rapid design, analysis, and assessment of Electronic Combat (EC) Systems has resulted in a requirement for an interactive analysis capability. The primary objective of this task was to develop an interchangeable graphics software package which would enhance the MMI and improve the human's capability to interpret and reduce data in the research, analysis and design of EC systems. The task encompassed the procurement of state-of-the-art graphics workstations and the development, modification, enhancement and rehosting of special purpose analysis, interface and graphics software.

Task Summary Results:

As part of the SAIC support provided under this task, two SUN SPARC workstations were purchased for the Air Force and installed at WPAFB in Dayton and at SAIC in Atlanta. Additional activities supported by this task included software requirements and design efforts, and the acquisition of Automated Scenario Generation System (ASGS) software and ADVISE™ software. In order to ensure source code could be provided for all ASGS processes as well as ensuring that object code and interface instructions would be available for ADVISE™/ASGS interface, the ADVISE™ and ASGS software were unbundled. Additional activities included modification of Situation Display and overlay process software packages to provide an interface to ADVISE™/ASGS software. Documentation was then generated for the ADVISE™/ASGS interface. In addition, an ASGS user's manual was developed. A man-machine interface was defined and then demonstrated. An MFD/ASGS interface was also designed and tested. A FORTRAN version of SUPR-GRAF™ to Ada was translated, documented and its demonstration capability was delivered to the Air Force.

2.2.16   TASK 89-0004   CONCEPT I DEMONSTRATION SUPPORT

AF OPR: Mr. Gil Kuperman
SAIC PI: Dr. William Perez

Task Objective:

The task objective was to prepare data bases and imagery required to support the Strategic Relocatable (SRT) Capability Concept I proof-of-concept demonstration experiment and to assist in establishing data collection requirements, provide data collection software, and prepare subject briefing materials.

Task Summary Results:

In preparation for the Concept I study, requirements for the Concept I proof-of-concept study were determined. These requirements included: (1) identifying the activities to be accomplished for conducting the study; (2) evaluating the results of the Automatic Target Cuing (ATC) performance evaluation to define the conditions for the study; (3) extracting 512 images from the ATC imagery data base; and (4) developing a study plan based on other requirements. Activities completed included: development and delivery to the Air Force of details of a baseline mission to be used as the basis for the study; development of ATC database to store radar imagery to be used to support the ATC study; and the development of a Combat Mission Folder tailored to the SRT mission. In addition, training and briefing materials were developed and delivered to the Air Force for use in the study. To assist in establishing data collection requirements, a plan and schedule were developed which took into account the participation of Logicon Technical Services Incorporated (LTSI) and Systems Research Laboratories (SRL) in this effort. SRL, under a subcontract agreement, implemented the data collection software. Two computer programs to perform real-time data collection were developed, as well as a program to process and correlate human performance data with ATC performance data.

2.2.17   TASK 89-0005   STRATEGIC FORCE MANAGEMENT FOR RELOCATABLE TARGETS (SFM/RT) SCENARIO ENHANCEMENT

AF OPR: Ms. Denise Wilson
SAIC PI: Mr. Steve Rizzi/Ms. Carol Mathews

Task Objective:

The Strategic Force Management for Relocatable Targets (SFM/RT) simulation was an investigation by AL into the conceptual definition and human factors requirements of a command and control facility (ground based or airborne)

for the dynamic management of strategic assets in the trans-Single Integrated Operational Plan (SIOP) period. Under this task, the existing SFM/RT scenario was to be assessed for completeness, accuracy, and consistency. Following this analysis, recommendations were to be made to AL regarding modifications to the scenario and simulation data bases.

Task Summary Results:

An analysis and review of the SFM/RT scenario were accomplished. As a result of this review, it was determined that several areas needed further assessments and recommendations to enhance scenario credibility with SAC and others in the SRT community. The areas of enhancement included MILSTAR satellite communciation system specifications as they impact the SFM/RT system and the development of a concept of operations (CONOPS) briefing for the SFM/RT system. The CONOPS briefing was developed to support the completion of Subtask 1, Scenario Enhancement. Documents were completed for both areas and delivered to the Air Force. In addition, the Storyboard document was completed and delivered to the Air Force.

2.2.18 TASK 89-0006 LOCAL OPERATIONS AND MAINTENANCE

AF OPR: Mr. Tom Green/Mr. Don McKechnie
SAIC PI: Mr. Robert Prior/Mr. John Stengel

Task Objective:

The task objective was to provide general operations and maintenance support for SACDEF facilities and associated hardware and software elements, including the B-1B High Fidelity Defensive Crewstation, B-52G Defensive Station and Instructor's Console, B-52 Digital Image Generator, PDGS, and CDGS. Activities were directed in support of the following subtasks: Mask-Fit subject testing, NVG Trainer, Aim Sight and Space Based Direct View Optical System (SpaDVOS) data reduction.

Task Summary Results:

Support activities consisted of technician support for B-1B ERS CLS, Aim Sight development, HFDCS, Color Study, RWR study, CITS integration, SpaDVOS development, MTQ, Anthropology Lab, OCM/CCD and B-52 DSS Upgrade activities. In addition, a new laser scanner was installed, a SUN workstation transferred from the MMI task was installed, ADVISE software on a SUN workstation was installed, the Aim Sight track handle problem was solved, and demonstrations were performed utilizing the B-1B simulator. Technician support was provided to each of the CFH labs. Continued support was accomplished under the follow-on task, Task 91-0006.

2.2.19   TASK 89-0007   INTEGRATED INFORMATION FOR STRATEGIC C³I

AF OPR: Maj Michael McFarren/Lt Col William Marshak/
Lt Col Michael Eller

SAIC PI: Mr. Lou Machuca

Task Objective:

The task objectives were to investigate, analyze, and model strategic Command, Control, Communication, and Intelligence (C³I) processes that occur in the decision making environment for the relocatable targets (RT) mission. SAIC used an operational prototype system to demonstrate the functionality and benefits of utilizing fused information sources to provide a foundation upon which to build requirements for a fully operational, integrated decision support system for senior decision makers concerned with the RT problem.

Task Summary Results:

Original requirements for the task included: analysis and documentation of existing intelligence and operating data bases; evaluation and modeling of the decision making process; development of a prototype Defensive Station Simulator (DSS) (Relocatable Target Integrated Plans/Intelligence (RIPI)); and documentation of study findings, experimentation activities, and development of requirements for full scale integration; and conduct and support briefings. An "IDEF_O" model was built to fully define the mission planning subtasks, their interactions and dependencies as well as requirements documentation outputs. After attending an Air Force sponsored Systems Architecture meeting, a document entitled "SRT Architecture Study" became available for review. It was after review of this document that the decision was made by the Air Force to not continue work on RIPI sub-task 1 (Systems Architecture) in order not to duplicate work.

Air Force direction was received to refocus the work toward the analysis and development of mission planning tools for SRT targeting problem. This analysis would lead to concepts by which SRT mission planning tools would be developed and prototyped. Data was obtained by observing SRT mission planning processes at SAIC, Belleview, New England. This data enabled development of an initial mission planning tool facade which completed work on sub-task 2.

In support of sub-task 3, an experiment was developed to evaluate human factors issues related to information display and an ideal mission planning tool. Results were used to develop a mission planning tool requirements document. This document was then used to build a working prototype of a SRT mission planning tool.

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2.2.20   TASK 90-0001   B-1B ENGINEERING RESEARCH SIMULATOR SUPPORT

AF OPR: Mr. Tom Green
SAIC PI: Mr. Robert Prior/Mr. John Stengel

Task Objective:

The task objective was to provide the operation and maintenance required for the Engineering Research Simulators (ERS) at specified B-1B Main Operating Bases. SAIC was contracted to provide operations and maintenance support, in accordance with the Integrated Support Plan, for the B-1B ERS at Ellsworth and Grand Forks AFBs. SAIC was tasked to: provide engineering and technical support for depot level maintenance of the B-1B ERS; plan, organize, and accomplish relocation of the B-1B ERS to WPAFB; and identify, analyze, and evaluate possible hardware/ software enhancements to the simula... to eliminate previously defined discrepancies and to enhance the functional capabilities for human engineering research and aircrew training.

Task Summary Results:

Operations and maintenance continued in support of B-1B Crew Training from the previous task at Ellsworth AFB and Grand Forks AFB. Reliability of the ERS at both locations averaged 98% over the task duration. Activities included development and check-out of B-1B CITS hardware; development of ERS baseline load using the results of the RWR, Flight Director and AMC studies; and OSO MFD screen modifications. In addition, CITS panels were developed, installed and demonstrated. Software enhancements to drive vertical situation displays (VSDs) were accomplished. Improvements were completed for the instrument landing system (ILS) and the aircraft auto pilot modeling. In addition, a software interface to the Raster Technology graphic generator was developed. A portion of the task SOW specified the relocation of the ERS to WPAFB. However, the Boeing B-1B WST did not achieve operational status at the specified time and a decision was made by the Air Force to continue contractor support of the ERS in the field until the B-1B WST would become operational.

2.2.21   TASK 90-0002   MANNED THREAT QUANTIFICATION

AF OPR: Maj Ed Fix
SAIC PI: Mr. Evan Rolek

Task Objective:

The Manned Threat Quantification (MTQ) program is responsible for quantifying the vulnerabilities of Soviet surface-to-air weapon crews. A variety of methods are used for this purpose including real-time man-in-the-loop simulations.

The objectives of this task were to develop data bases, models including neural nets, and technical reports. Products from this project were to be used for tactics development and evaluation, training, and mission planning.

Task Summary Results:

Task activities included design and conduct of experiments as required by the Air Force using accepted human factors engineering guidelines. Experiments used the interactive simulation approach as opposed to the traditional "stimulus-response" type of study. All experiments were accomplished using the Surface to Air Missile (SAM) simulator linked to the B-52 Defensive Crewstation (T-4). In addition, a neural net model was developed and trained. After the development of the neural net model, the performance of the net was then compared to the performance with that of the SAM crew. The documentation for these experiments was delivered.

2.2.22   TASK 90-0003   ADVANCED TARGET ACQUISITION
                          SYSTEM (ATAS) CONCEPTUAL STUDIES

AF OPR: Lt Col William Marshak/Dr. June Skelly
SAIC PI: Mr. Jack Houchard/Ms. Janet Irvin

Task Objective:

ATAS consists of an unmanned air vehicle which carries a sensor deployed from a host strike vehicle such as a B-52; sensor video is transmitted to the host, providing up-to-date target position and threat laydown. The purpose of this task was to establish system performance requirements for ATAS concepts, and to evaluate the utility of ATAS in performing Strategic Air Command (SAC) maritime and rolling stock missions through simulation.

Task Summary Results:

The ATAS concept, mission, and target imagery used in the man-in-the-loop simulation represents a single point along a continuum for system design and evaluation. A personal computer-based research simulator using stored photographic imagery was integrated and installed in AL/CFHI facilities to support this task. A research plan was developed and a study was subsequently performed. This study demonstrated the utility of an ATAS concept, and that radar navigators (RNs) can potentially use the information provided by an ATAS to enhance mission success. Furthermore, the study illustrated a unique method of employment of unmanned aerial vehicles (UAVs); that is, ATAS represents a force multiplier that serves as an adjunct to the strike aircraft, providing crews with a self-contained capability for advanced reconnaissance, target acquisition, threat avoidance and bomb damage assessment with increased survivability. The empirical results indicated that subjects could use ATAS to improve their decision process for

selection of the optimum attack plan. The optimum attack plan was selected between 53% to 73% of the time, resulting in a substantial reduction in the required number of sorties. Therefore, these results suggest that ATAS with sensor resolution, flight parameters, and a man-machine interface similar to that used in this study would serve as a force multiplier.

The subjects (i.e., experienced radar navigators) were highly in favor of the ATAS concept and their comments are consistent with the empirical results of the simulation. Generally, the subjects stated that this study showed the utility of an ATAS concept and that subjects can potentially use the information provided by an ATAS to enhance mission success. Completion of the technical report was accomplished as part of an O&M Special Project.

2.2.23   TASK 90-0004A   OPTICAL COUNTER MEASURES (OCM) EFFECTIVENESS ESTIMATES

AF OPR: Capt Michael Dowler
SAIC PI: Dr. Gregg Irvin/Ms. Tracy Donohue/Mr. Jeff Doyal

Task Objective:

The task objective was to provide technical support in the analysis and evaluation of various optical countermeasures and optical counter-countermeasures against systems and the human visual system. Support was to be provided for experimental design, equipment configuration, data collection and reduction for various psychophysical experiments analyzing the differential effects on performance of various OCM techniques. Specific attention was to be directed to the effects of OCM on crew system effectiveness in an operational context. Various performance metrics which were to be evaluated range from acuity measures and color discrimination to workload and aircraft attitude control.

Task Summary Results:

Primary support activities were conducted in the areas of laboratory support and support of the Advanced Vision Concepts 1 (AVCON) program.

Laboratory support included completion of data analysis on two laser countermeasures experiments involving the evaluation of laser-protective visors. The first experiment involved measuring aircrew performance as a function of countermeasure power levels during a simulated terrain following task. The second experiment examined air-to-ground target acquisition performance during simulated air base attack maneuvers.

Dr. Gregg Irvin (SAIC) and Capt Michael Dowler (AL) co-authored a paper entitled "The Effects of Continuous-Wave Laser Countermeasures and Laser Protective Visors on Simulated Terrain Following and Targeting Accuracy" at the

Ocular Hazards on Flight and Remedial Measures Symposium, Advisory Group for Aerospace Research and Development. This paper described the results of the visor evaluations.

SAIC developed and tested a laser atmospheric modulation simulator (LAMS) for use in optical countermeasures experimentation.

In support of the AVCON Program, a concept evaluation and psychophysical test plan was developed for spatial, spectral, and temporal prototype laser protection devices.

Additional support for this project included the development of pilot visual field of view maps from the cockpit of F-15, F-16, and A-10 aircraft.

2.2.24   TASK 90-0005B   DECEPTIVE TECHNIQUE EVALUATION (CCD)

AF OPR: Capt Michael Dowler
SAIC PI: Dr. Gregg Irvin/Ms. Tracy Donohue/Mr. Jeff Doyal

Task Objective:

The task objective was to provide technical support in the development, analysis and evaluation of various camouflage, concealment and deception (CCD) related practices. The emphasis of these CCD evaluations was to develop solutions to Air Force operational problems, including aircraft visual signature reduction techniques, air base tonedown and camouflage practices, developing shape disruptive and masking patterning, and decoy design and evaluation. Contractor support was to be provided for experimental design, equipment configuration, data collection and reduction activities for various experiments analyzing CCD effectiveness. Technical and programmer support was to be provided to maintain and upgrade the program equipment as necessary to conduct experimentation.

Task Summary Results:

DECOY DEVELOPMENT

A number of full-scale two-dimensional silhouette aircraft decoys were developed and produced for use at the Creek Shadow CCD demonstration. These first-generation aircraft decoys included a KC-135, an F-15, and two F-16 silhouette decoys. Additionally, two aircraft masking patterns and two hardened aircraft shelters (HAS) were developed in support of the Creek Shadow CCD exercise. The 2-D decoys portrayed the silhouette of the aircraft (or HAS) created by a point source of light oriented at an air-to-ground attack perspective with regard to the aircraft. Thus, when viewed from an attack perspective, the 2-D decoy appears to have 3-D characteristics.

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Further development of these aircraft decoys resulted in the production of three 2-D F-16 decoys with internal contrast. These second generation decoys appear much more realistic at close ranges due to their internal coloration.

FIELD TEST SUPPORT

Support was provided for the Creek Shadow and Camouflage Airbase Leipheim (CABLE) CCD field tests. Support activities included the deployment of various CCD treatments, the development of aircrew pre-mission and post-mission briefing materials, and the collection of data including aircrew interviews and questionnaires, HUD/Sensor tapes, and Radar Bomb Scoring (RBS) data. The data from Creek Shadow was subsequently collected, extracted, analyzed, and published in three technical reports which are awaiting security classification prior to publication.

EXPERIMENTATION

Two in-house laboratory experiments were conducted to evaluate the feasibility and effectiveness of a 2-D silhouette KC-135 aircraft decoy. These experiments utilized the Silicon Graphics 3-D computer flight simulator and the Real Target View Simulator (RTVS).

An effective color scheme for a dual-sided false operating surface (FOS) was developed using a forced-choice color discrimination experiment presented on the LUMENA™ image processing system.

Using an "equivalent contrast reduction" technique, an experiment was conducted that investigated the effects of infrared-visible obscurant on air-to-ground sensor-aided target acquisition. This issue was addressed using a modified and enhanced Silicon Graphics flight simulation program to conduct man-in-the-loop flight simulation of attack profiles in which various levels of obscuration in the thermal infrared domain were simulated.

TEXTURE IMAGE PROCESSING SYSTEM (TIPS)

Texture Image Processing System (TIPS) is a Silicon Graphics based system designed to provide a computational method of developing ideal masking patterns and camouflage techniques. TIPS incorporates traditional image processing and Fourier methods with functions derived from human vision models. All portions of TIPS except some of the Fourier techniques were completed during this contract period.

SAIC presented the results of laboratory studies at five different symposia. The contractor produced three technical reports documenting research activities conducted at Creek Shadow CCD Demonstration.

2.2.25   TASK 90-0006   B-1B ERS MODIFICATION (FLIGHT DIRECTOR STUDY)

AF OPR: Mr. Brad Purvis
SAIC PI: Mr. Roger Overdorf

Task Objective:

The Flight Director Study was a B-1B SPO/AL project that involved the implementation of new B-1B flight director control (FDC) laws in the B-1B Engineering Research Simulator and the conduct of a piloted evaluation of the existing and new control laws. The objective was to implement the new control laws, evaluate replacement graphics units for the pilots' Vertical Situation Displays (VSDs), assist in the experiment in terms of developing the data collection software and reducing the collected data in the study in preparation for a final report.

Task Summary Results:

The Flight Director Study was a B-1B SPO/AL project that implemented new B-1B flight director control (FDC) laws in the B-1B Engineering Research Simulator and the conduct of two piloted evaluations. The first evaluation concentrated on the differences between the existing and new control laws. The second evaluation primarily focused on VSD format symbology issues. Program activities occurred over a relative large time span, August 1989-May 1991, and involved six distinct phases; Phase I development , Phase I data collection, Phase I data reduction, Phase II development, Phase II Data collection, and Phase II data reduction.

Phase I development extended from July 1989 to November 1989. Phase I included analysis and modification of the existing ERS Altitude Hold; Tactical Air Navigation (TACAN), Localizer and Glide Slope algorithms; analysis of the VSD graphics system; acquisition of a more capable system; the development and integration of simulation control/data collection algorithms; and the implementation and test of the new Collins Altitude Hold, TACAN, Localizer, and Glide Slope algorithms.

Data Collection for Phase I occurred in November of 1989 at Grand Forks AFB. A total of nine pilots performed 24 different combinations of flight director software, wind conditions, and approach scenarios for a total of 216 data runs. The data was collected using "loaner" graphics units more powerful than "stock" ERS

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units but less powerful than those on order from Raster Technology, Inc. Collected data was returned to WPAFB for analysis. Phase I data reduction occurred from late November 1989 through March 1990. A collection of parameters was extracted for each of three regions of each data run. Plots of the data and raw data for inclusion in SAS were provided in March. Phase II development began nine months later and concluded in February 1991. Anomalies identified in the Phase I study were corrected and retested. A series of changes to new VSD graphics software improved update rates from 6-8 Hz to 16 Hz. The specifics of these changes were detailed in a memo to AL engineers. The more powerful Raster Technology 385 units were installed for the Phase II tests. Phase II data collection began late in March 1991 at Grand Forks AFB. Data were collected from twelve subjects resulting in 192 data runs. The packs were shipped to WPAFB for data reduction. Phase II data reduction occurred from April through May 1991. Collected data was examined, "massaged" to create several secondary parameters, windowed and exported via tape to the AL Falcon VAX system for further analysis.

2.2.26 TASK 90-0007 SILHOUETTE DECOY OPERATION

AF OPR: Capt Michael Dowler
SAIC PI: Dr. Gregg Irvin

Task Objective:

The task objective was to provide operations and maintenance support during the implementation, analysis, and evaluation of various enhancements to the expanded silhouette decoy concepts developed through the camouflage, concealment, and deception program. The enhancements involved visual, thermal and radar concepts designed to solve Air Force operational problems.

Task Summary Results:

SAIC provided O&M support for the implementation, testing and evaluation of various enhancement concepts to the 2-Dimensional Silhouette Patterns as they related to integrated visual CCD approaches and integrated multi-spectral approaches to air base survivability. Support included providing the necessary human factors engineering and statistical analyses support to analyze the data collected and document the decoy expansion efforts.

The development effort was a joint venture between HQ SAC/XOBS and Armstrong Laboratory to test the feasibility of using the 2-D decoy technology for large aircraft types. A full-scale prototype KC-135/Airborne Warning and Control System (AWACS) 2-D decoy was developed. This decoy was first evaluated in the laboratory using both computer simulations and field imagery of scale models. The laboratory results were favorable and showed both high levels of deceptive effectiveness for the decoys and large delays in the visual acquisition of the real aircraft.

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The decoy was then field tested at the Creek Shadow 1990 demonstration. The decoy was deployed on two different surfaces: Aeronautical Systems Division's concrete false operating surface and a concrete ramp area leading from a parking pad area to the runway. A final report was delivered to SAC/XOBS and a technical report was submitted for publication.

2.2.27   TASK 90-0008   STRATEGIC DEFENSE TIMELINE ANALYSIS AND MODELING

AF OPR: **Maj Michael McFarren**
SAIC PI: **Mr. Russ Moody**

Task Objective:

The task objective was to conduct high level analysis and modeling of selected U.S. strategic defense organizations and operations in support of the Ballistic Missile Defense (BMD) Timeline model being developed under a separate contract. The primary focus of this task was to be on systems analysis and the development of a descriptive model of the U.S. National Command Authority (NCA) operations. Areas focused upon included: BMD Timeline Model Evaluation; "IDEF^0" Model Development; and Petri Net Model Development.

Task Summary Results:

The "IDEF^0" Model Development subtask consisted of three activities: systems analysis, threat scenario evaluation and "IDEF^0" Model Development. Systems analysis consisted of assessing the organizational structures and information processes associated with a U.S. response to a strategic attack on the continental U.S. Emphasis was on the NCA and its interrelationships with North American Air Defense Command (NORAD), SAC, and the U.S. Space Command. SAIC expanded four threat scenarios provided by Armstrong Laboratory in support of the systems analysis. The results of the systems analysis was presented in the form of "IDEF^0" diagrams. Activity sequence diagrams (ASDs) were developed for each of the strategic organizations included in SAIC's systems analysis. The ASDs were revised based on comments received during SAIC's visit to United States Space Command. The final ASDs included both the input/output mechanism/control information needed for the "IDEF^0" diagrams and the activity sequence and timing information needed for the Petri net model. Modeler 1 Petri net software was installed on the GFE Sun workstation within AL/CFHI facilities at WPAFB.

Additional activities for this task included the use of a consultant, Mr. Daniel Snyder, who completed a literature survey of analytical and diagramming techniques, semantic networks, machine learning, rule-based systems and hyper documents. This survey provided the initial background for choosing concept

mapping, IDEF^0, and storyboard protyping as techniques for use in this effort. In addition, a subcontract with Meta Software Corporation was to develop an initial implementation of Design/CPN to support timed Petri nets and the Super Automatic Mode software was developed. Meta delivered the "Super Automatic Mode Enhancement" software and "Super Automatic Code Generation" instruction/documentation to SAIC. Testing was performed by SAIC and delivered to the Armstrong Laboratory.

Evaluation of the BMD Timeline model Petri net specification was not accomplished by Air Force direction because the specification was not available prior to the conclusion of the SAIC effort. Resources budgeted for this activity were transferred to the "IDEF^0" Model Development activity.

2.2.28   TASK 90-0009A   TECHNOLOGY ASSESSMENT AND PROTOTYPING FOR THE ADVANCED TACTICAL VIRTUAL COCKPIT SIMULATOR (TAP/ATVCS)

AF OPR: Mr. Michael Haas
SAIC PI: Ms. Teresa McKelvey

Task Objective:

The task objective was to develop and evaluate advanced computational system architectures for the Technology Assessment and Prototyping for the Advanced Tactical Virtual Cockpit Simulator (TAP/ATVCS) task. In support of this effort, selected architectural components, various implementation language approaches, and interprocessor connectivity components were to be evaluated.

Task Summary Results:

Trade studies and literature reviews in support of an optimal system architecture, simulator components, and software language were accomplished. Based on technical discussions with AL, a design approach for this task was selected.

The TAP/ATVCS is a personal computer (PC)-based flight simulation implemented with a shared memory architecture distributed across multiple processors. The operator can perform simulation flight maneuvers utilizing the mouse and two associated mouse buttons. This allowed the aerodynamics model to be tested.

Four low fidelity models were integrated and executed on the simulation PC. These models were the aerodynamics, atmospheric, navigation, and electronic warfare weapon system (EWWS) (from VCASS). The low fidelity aerodynamics model primarily moved the aircraft. Given a roll and pitch command and an airspeed, the model computed the new X, Y, and Z location of the aircraft. The low fidelity atmospheric model computed the pressure and density of the air based upon

the atmospheric type (i.e., polar, cold, hot, tropical, standard) and the altitude of the aircraft. The atmospheric model utilized a table lookup method to obtain the desired data values. The EWWS model from the VCASS source code was also integrated into the ATVCS low fidelity simulation code. Pertinent information from each of the four models was displayed in the textual information area of the instructor-operator station screen. This allowed the operation of the models to be observed.

The instructor-operator screen was divided into three sections: a gaming area, a pitch indicator, and a textual information area. The terrain in the gaming area was represented as a grid pattern. The desired flight path was displayed as line segments with the waypoints being consecutively numbered circles. One threat (a tank) was displayed as a simple rectangle. The aircraft symbol was displayed as it flies through the gaming area.

Although the basic architecture and several of the models were implemented, the task did not address the full range of design goals as a result of Air Force funding cuts.

2.2.29   TASK 90-0010B   AUTOMATED DEFENSIVE MISSION PLANNING SYSTEM REHOST (ADMPS)

AF OPR: Mr. Earl Sharp
SAIC PI: Mr. Michael Sargent

Task Objective:

The task objective was to rehost the ADMPS prototype software from the VAX to a SUN workstation running ADVISE™ in an Ada development environment.

Task Summary Results:

The ADMPS demonstration system was successfully rehosted from the VAX/VT 240 system to the SUN SPARCstation using an Ada development environment and SAIC ADVISE™. Software was developed for the demonstration system which allowed a user to create/edit a mission route, select and place threat systems in a realistic manner, and perform various map and threat manipulations. Software was also developed to create a proof of concept interface with the Concurrent computer and ERS/HFDCS Simulation. The ability to create a mission with ADMPS and download the data to the HFDCS Simulator was demonstrated. In addition, an ADMPS Threat Database and Command Level Database were developed. The Threat Database contained mode and signal information specific to each threat to support realistic simulation of the threat environment. The Command Level Database contained information required to accurately generate a doctrinally correct mission laydown based on user selections. As a result of task

accomplishments, AL has the capability to more efficiently generate realistic B-1B ERS, HFDCS, and B-2 Prototyping and Evaluation System (P&ES) threat data bases for research applications.

2.2.30   TASK 90-0012   B-52 FLIGHT TEST SUPPORT

AF OPR: Capt Stu Turner/Lt Col William Marshak
SAIC PI: Mr. Jack Houchard

Task Objective:

The task objective was to develop an airborne data collection computer and a ground based data reduction and analysis computer to support flight test operations. The airborne system would collect and store data from a MIL-STD-1553 interface and a GPS receiver. An analog interface for collecting physiological data could be developed in follow-on tasks. The data reduction system would accept data from the airborne system and produce tabular files for printing or plotting; this system would also be equipped to digitize and extract character data from data annotated on video.

Task Summary Results:

The airborne data collection computer developed for this task consisted of an MS-DOS based industrial process control processor, a six slot IBM-ISA based passive backplane housed in a rugged industrial chassis. The system also contained an 80 M-Byte hard disk drive and a 1.44 M-Byte floppy disk drive. The chassis was modified to incorporate two power supplies utilized to adapt airborne 28 VDC power to computer required power, a Trimble Navigation global positioning system (GPS) receiver, a Ponsor MIL-STD-1553 data bus adapter, and a Reflection Technologies Private Eye Display Adapter. Software for collecting and recording time tagged data from the 1553 and GPS interfaces was also developed. This package was successfully demonstrated, accumulating over fifteen hours of flight time on a B-52 aircraft.

The ground based data reduction and analysis computer was developed for three purposes: to provide a high speed computational platform for reducing and analyzing flight test data; to provide a platform for recognizing and extracting character data annotated on video; and to provide a software development environment for creating airborne system software. For data reduction activities, the computer consisted of a 33 MHz, IBM PC compatible 80486 based processor, a 335 M-Byte hard disk drive, 5.25 and 3.5 inch floppy disk drives, and a 16-inch color monitor. Several commercial software applications were obtained for reducing and analyzing the data, including MicroSoft Excel, MathCad, Powerpoint, and MicroSoft Word. Additional commercial software was acquired to support the third task objective, specifically a Microsoft C compiler.

Additional equipment was purchased for recognizing and extracting character data annotated on video. Specifically, the data reduction system was equipped with a high speed video frame grabber/digitizer and display adapter. Software was written, based on an AL provided neural network character recognition algorithm, to identify the character data regions within the frame; to identify the exemplar sets to be used for training the network; to train the neural network; and to perform near-real-time recognition and storage.

2.2.31   TASK 91-0001   B-1B ENGINEERING RESEARCH SIMULATOR SUPPORT

AF OPR: TSgt Robert Stewart
SAIC PI: Mr. Gene Welch

Task Objective:

The task objective was to provide the operation and maintenance of the Engineering Research Simulators at specified B-1B Operating Bases. Under this task, SAIC developed and implemented an Integrated Support Plan to accommodate the deployment of the B-1B Egnineering Research Simulator at Ellsworth and Grand Forks AFBs. The plan included support equipment requirements, spares and parts provisioning, management, reporting methodology, technical data, training, transportation, packaging and storage. Provisions were made to develop a software update to track aircraft software releases.

Task Summary Results:

Technical support continued at the field sites and depot support continued at the SAIC Dayton and WPAFB facilities. During this period, the Air Force made the decision to drop the computational system contract maintenance support for the two field locations. Computational support continued without interruption or lost time. CITS panel test and evaluation continued and field support was provided to identify ERS requirements associated with B-1B system upgrades. In April 1991, B-1B ERS shipset #1 was relocated from Grand Forks AFB ND to the SAIC facility at Dayton, Ohio. The flight station was disassembled to allow installation in B-03, Building 248, WPAFB. The flight station was reassembled, tested, and became operational in early May 1991. The computational system and aft station were placed in storage at the SAIC Dayton facility.

On 30 June 1991, operational support was terminated for the B-1B ERS shipset #2 located at Ellsworth AFB, South Dakota. The computational system and supporting hardware were shipped to SAIC's Dayton facility in July 1991. The remainder of the ERS #2 shipset was placed in storage at Ellsworth AFB SD. The composite ERS system availability for training exceeded 98% for the entire support period from 1987-1991.

2.2.32 TASK 91-0003 STRATEGIC FORCE MANAGEMENT FOR RELOCATABLE TARGETS (SFM/RT)

AF OPR: Ms. Denise Wilson
SAIC PI: Ms. Carol Mathews

Task Objective:

The task objectives involved providing analysis of the SFM/RT system functions. The SFM/RT task identified critical SFM/RT functions in the areas of intelligence fusion, assessment, replanning, force allocation, and force direction; decomposed these functions to demonstrate inter-connections between crew positions and automated processes; and described decision support system requirements.

Task Summary Results:

Due to the changing worldwide political environment, an impact analysis was required for the new environments on SAC assets. This analysis resulted in publication of a Guidebook. A more detailed analysis was then performed on SAC assets placed in the new force structure and the systems they would interact with or depend on. This analysis culminated with the publication of a Final Technical Report.

2.2.33 TASK 91-0004A NIGHT VISION GOGGLE (NVG) NIGHT IMAGING THREAT EVALUATION (NITE) LAB

AF OPR: Mr. Brad Purvis
SAIC PI: Mr. Robert Norton

Task Objective:

The task objective was to provide assistance in the design and construction of a NITE Lab/Test Lane. This unique engineering/training device is designed for aircrew Night Vision Goggle (NVG) applications using commercial-off-the-shelf equipment modified for NVG training and evaluation. The NITE Lab would be used to train aircrews in initial and graduate level NVG operations. Embedded within this system would be the capability to evaluate aircrew members' progress and proficiency at employing NVG's. The NITE Lab would be used to simulate normal and emergency operations while wearing NVG's in a light tight room. The task would provide delivery of four of these devices to Hurlburt, Pope, Ellsworth, and Kirtland AFBs.

Task Summary Results:

The NITE Lab development task supported an AL/CFHI objective to develop a modular NITE Lab training facility to support the training of Air Force crewmembers in the proper operational use of Night Vision Goggles (NVG).

The task was partitioned into two phases. Phase One developed a prototype design of the NITE Lab in accordance with system requirements specified by AL/CFHI. The prototype design utilized commercial-off-the-shelf equipment wherever possible to meet system requirements. An exception to this was a prototype terrain model developed by Liberty Graphics and moonlight system developed by SAIC. Upon completion, the prototype NITE Lab system was delivered and installed by SAIC at Kirtland AFB. An operational acceptance test was performed by AL/CFHI. Following successful completion of acceptance testing, an evaluation of the prototype at Kirtland AFB was performed at Williams AFB. Upon completion of evaluation, all comments and updates for the NITE Lab configuration were incorporated as a revision to the system requirements specification. The revised system requirements became a production specification for Phase II of the NITE Lab task.

During Phase II of the NITE Lab task, three NITE Labs were developed in accordance with the new production specification Two NITE Labs have been installed and accepted at Ellsworth AFB and Hurlburt Field. The third NITE Lab was installed and integrated at McGuire AFB as the final activity accomplished under the SACDEF contract. Development of these NITE Lab systems by AL and SAIC has provided improved training and crewmember readiness for Air Force night missions requiring the use of NVGs.

2.2.34   TASK 91-0006   LOCAL OPERATIONS AND MAINTENANCE

AF OPR: Mr. Don McKechnie
SAIC PI: Mr. Gene Welch

Task Objective:

The task objective was to provide general operations and maintenance support of SACDEF facilities and associated hardware and software elements including the B-1B high fidelity crewstation, B-52G defensive station and instructor's console, B-52 flight test, PDGS, CDGS, and ERS. Activities are directed in support of the following subtasks: O&M general support, SpaDVOS, B-2 studies, Color Study (CDGS), PST, Multimedia Laboratory/Crew Briefing Room (ML/CBR), LANTIRN, NVG NITE Lab, and SACDEF Technical Library.

Task Summary Results:

Task activities included the general operations and maintenance support of SACDEF facilities and associated hardware and software elements. Principal support to hardware systems and components included O&M for the B-1B ERS flight station, the B-1B High Fidelity Defensive Crew Station (HFDCS), B-52 G defensive station and instructor's console, B-52 flight test, PDGS, CDGS, and Integrated Helmet And Display Site System (IHADSS). Activities directed in support of studies, tasks, and other activities included: SpaDVOS, B-2 studies, Color Study, Postload Systems Trainer (PST), LANTIRN, NVG NITE Lab, the SACDEF Technical Library, B-1B ERS/HFDCS demonstrations, facility engineering modifications, and security management and control. O&M support provided to SACDEF permitted day-to-day operations and special projects to be efficiently accomplished with minimal delays as a result of equipment down-time.

2.2.35 TASK 91-0007   B-2 COCKPIT EVALUATION FACILITY (CEF)

AF OPR: Mr. Earl Sharp
SAIC PI: Mr. John Stengel/Mr. Roger Overdorf

Task Objective:

The task objective was to provide the necessary assistance to AL/CFHI in the development of a B-2 Cockpit Evaluation Facility to support human engineering evaluations of existing and proposed B-2 crewstation systems.

Task Summary Results:

Program activities started in June 1991 and continued through contract completion. There were four distinct program phases: initial program design and planning, Milestone I development, Milestone II development, and Milestone IIA development.

Initial program activities started in June 1991 and progressed through December 1991. An accelerated set of development activities were authorized to enable some parallel development along with the planning activities. Development of generic strategic bomber models started in August to capitalize on available manpower. A survey of the available rapid-prototyping tools was completed quickly in order to allow lead time in the procurement of rapid-prototyping hardware and software. Three Silicon Graphics workstations and a copy of the VAPS rapid prototyping tool were subsequently procured. Training for the graphics systems occurred in October 1991. Once funding for all task activities was authorized, development of program planning and control documents began. A Program Plan and schedule, a Systems Engineering Management Plan, a draft Software Development Plan, and a draft Configuration Management plan were generated. System design activities were started including the development of a

design specification. Tentative design requirements were identified and a draft architecture developed to include existing and anticipated assets. A significant program redirection by the Air Force occurred in December 1991 which eliminated most of the anticipated funding for the program. Further development of planning documents was terminated.

Milestone I (MS I) activities ran from mid-December 1991 through early April 1992. During MS I, significant portions of the CEF interim cockpit or "hotbench" were developed. A crewstation cockpit with stick, throttles, rudder pedals, and touch-screen was procured and integrated. A linkage processor was identified and code developed to read control inputs from the cockpit and transmit the results on a local area network (LAN). The Silicon Graphics workstations were installed in the Building 248 and interconnected to the LAN. A systems test consisting of a dynamic VAPS prototype was created to graphically demonstrate the operation of each of the cockpit controls.

Milestone II (MS II) activities started in late February 1992 and were completed in mid-September 1992. During MS II, development of generic strategic bomber models was completed. A set of data translation software was developed and an Ethernet interface purchased for the Concurrent Computer System to allow control data to be collected from the network and model data to be sent to the Silicon Graphics units. The VAPS rapid prototyping tool was used to create or integrate seven MDU formats including the VSD, HSD, "STATS," "FUEL," "ENGINE," "WEAPONS," and Flight Control formats. Data collection software was developed to record digital data to disk in real time. Data reduction software was developed to examine previously recorded data, generate statistics, and export data to other platforms. An Experimenter station was developed using VAPS and a Silicon Graphics Workstation that enabled experiment control and limited monitoring. Systems tests were conducted to assure development goals had been reached.

Milestone IIA (MS IIA) activities began at the conclusion of MS II and were a direct extension of the Milestone II activities. MS IIA activities were completed in January 1993. The goals of MS IIA as related to the hotbench cockpit were to add a moving map capability to the experimenter's station, add functionality to many of the existing MDU formats (primarily in Northrop developed formats), investigate Ethernet communication problems, and add the threat situation display (TSD) MDU format.

2.2.36 TASK 91-0008   ROBOTIC AIR-TO-AIR COMBAT (RAAC) VEHICLE INTEGRATED AVIONICS

AF OPR: Lt Col Michael Eller
SAIC PI: Mr. Jack Houchard

Task Objective:

The task objective was to assist the Flight Dynamics Directorate of Wright Laboratory (WL/FIMM) in defining the integrated avionics suite of a robotic air-to-air combat vehicle (RAAC). The RAAC vehicle was envisioned to provide lethal protection against enemy fighter aircraft when deployed by the pilot as an expendable, beyond visual range weapon. As requested by WL/FIMM, this work is being performed under subcontract by the Georgia Tech Research Institute (GTRI).

Task Summary Results:

The task originally consisted of five subtasks: 1) Requirements Definition, 2) Conceptual Design, 3) Technology Assessment, 4) Demonstration Program Definition, and 5) Planning. Funding constraints only allowed performance of subtasks 1 and 2.

During requirements definition, an operational scenario and baseline configuration for the RAAC vehicle were defined, and key assumptions identified. Based on this concept, a loose partition of responsibilities between the RAAC and the mother ship was developed, and RAAC avionics responsibilities and requirements defined. Additional data requirements for the principal weapon, the air-to-air Stinger, were identified and GTRI entered a proprietary rights agreement with General Dynamics to obtain the data.

The conceptual design considered ongoing efforts being conducted by the Unmanned Aerospace Vehicle (UAV) Project Office, particularly in the common avionics initiatives. The Stinger data, as well as the UAV common avionics information were used to synthesize an avionics architecture which takes maximal advantage of existing avionics tailored to the unique mission of the RAAC. The architecture identified specific components, both existing and custom, as well as their responsibilities and high level interfaces.

Results of subtasks 1 and 2 were documented in a final report, which was submitted directly by GTRI to WL/FIMM, as well as a final briefing of the results.

2.2.37 TASK 92-0001 JOINT TEST AND EVALUATION (JT&E) FOR CAMOUFLAGE, CONCEALMENT AND DECEPTION PROGRAM (CCD)

AF OPR: Capt Michael Dowler
SAIC PI: Dr. Gregg Irvin

Task Objective:

The conduct of the Joint Camouflage, Concealment, and Deception Joint Test and Evaluation (JCCD) Program will resolve Program Critical Issues which address the effectiveness and suitability of camouflage, concealment and deception equipment and techniques for mission-critical fixed facilities and relocatable assets will be quantitatively determined. The objective of this task was to develop a detailed Program Test Design (PTD) document for the JCCD. This document served as the basis for the development of the Program Test Plan and the Program Database Managment and Analysis Plan, and the basis for preparation of specific site test plans for NAS Fallon, MCAS Cherry Point, Eglin AFB, Volk Field NG, Cold Lake Air Weapons Range, NWC China Lake, and MCAS Yuma.

Task Summary Results:

The Program Test Design (PTD) document was completed and approved by the JCCD Test Director and the OSD Technical Advisory Board. The document detailed the requirements and information necessary for the development of the JCCD Program Test Plan, the Data Base Management and Analysis Plan, and the various Site Specific Test Plans. The conduct of the JCCD based on the PTD will allow for the quantitative evaluation of the effectiveness of CCD against threat weapons systems that could be employed to reduce the survivability of U.S. mission critical resources. The threat consists of manned aircraft platforms using multi-spectral navigation and target acquisition systems to deliver conventional munitions and guided weapons. The JCCD test verification will provide the quantitative documentation required to serve as the basis for developing service guidance documents for commanders and service engineers to determine what CCD resources should be committed in the design or employment of an integrated passive defense strategy.

2.2.38 TASK 92-0002A B-1B POSTLOAD SYSTEMS TRAINER (PST)

AF OPR: Lt Col James LaSalvia
SAIC PI: Mr. Harold Dean

Task Objective:

This task was a cooperative venture between AL/CFHI and the 12th FTW/MAN, Randolph AFB, TX. The purpose of the task was to provide selected electronics subsystems and software necessary to perform the postload checklist training in the B-1B Armament Systems Trainer. The units developed were to be based on the designs in the B-1B Engineering Research Simulator (ERS) and the B-1B High Fidelity Defensive Crewstation Simulator (HFDCS). Four sets of equipment were to be provided under this task to the 12th FTW/MAN.

Task Summary Results:

The four required PST systems were integrated, assembled, tested and delivered to Randolph AFB. The PST hardware consists of a processor/linkage unit, a matrix, a lighting power supply, an instructor console, and the specified set of simulated panels and displays. The software load provides a man-in-the-loop simulated checklist with training-specific modifications. Two software utilities have been developed: the diagnostic package and the Weapon Configuration Tool. The diagnostic package provides hardware specific utilities for testing panels and displays. The Weapon Configuration Tool provides an automated, menu-driven method of generating aircraft weapon load configurations in the field to support dynamic training requirements. After integration into the B-1B Armament System Trainer, B-1B load crews will be provided with an opportunity to receive more thorough and comprehensive training than previously available.

2.2.39 TASK 92-0003 LOW ALTITUDE NAVIGATION AND TARGETING INFRARED FOR NIGHT (LANTIRN) II

AF OPR: Capt Stu Turner
SAIC PI: Ms. Janet Irvin

Task Objective:

The task objective was to assist AL/CFHI in the conduct of pilot workload analyses of Low Altitude Navigation and Targeting Infrared for Night (LANTIRN) equipped F-16s in support of the LANTIRN II Technology Insertion Effort. There were two basic objectives associated with this task. The first objective was to provide editing and reproduction support of FLIR video data gathered during LANTIRN II flight tests. The second objective was to conduct human engineering

analyses in order to: evaluate second generation FLIR, evaluate Automatic Target Cuer (ATC) technology, and measure pilot workload.

Task Summary Results:

Activities for this task were suspended due to a delay in the Air Force flight test/data collection schedule. This delay was due, in part, by problems encountered by Martin-Marietta with the development and implementation of the automatic target cuer (ATC). Activities planned for completion by 15 January 1993 include equipment preparation and packaging in anticipation of flight test resumption early next year.

2.2.40   TASK 92-0004   MULTIMEDIA LABORATORY/CREW BRIEFING ROOM (ML/CBR) TECHNICAL SUPPORT

AF OPR: SSgt Wiley Wells
SAIC PI: Mr. Gene Welch

Task Objective:

The task objective was to provide technical assistance as required to support the Human Engineering Division, Armstrong Laboratory (AL/CFH) in the development and interface of human engineering activities and tasks with multimedia capabilities to support human evaluations, analyses and studies.

Task Summary Results:

A senior audio/video engineer was assigned full time to this activity and has been providing operations and maintenance support for all multimedia hardware and the overall ML/CBR facility. Specific tasks accomplished have included identifying requirements (hardware/software) for components and interfaces, ordering materials, and producing video/audio products. In addition, technical advice and counsel have been provided to the Director of AL/CFH in video/audio matters. Once completed, the multimedia laboratory will provide AL with a state-of-the-art briefing room to support crew briefings and technology demonstrations.

2.2.41 TASK 92-0005 VTOL EFFECTIVENESS IN COMBAT/TACTICAL REGIMES (VECTR)

AF OPR: Lt Col Michael Eller
SAIC PI: Mr. Barry Michel/Mr. Harry Heaton

Task Objective:

The U.S. Army Aviation Systems Command (AVSCOM) Advanced Systems Research and Analysis Office (ASRAO) is developing advanced methods for the analysis, conceptual design, and systems synthesis of advanced Vertical Take-Off and Landing (VTOL) aviation platforms. This advanced methodology is being applied to the VTOL Effectiveness in Combat/Tactical Regimes (VECTR) project. The objective of this task was to provide technical support to the Systems Concepts and Analysis Team and the VECTR Project in the development of advanced systems engineering methodology and advanced on-board systems concepts, including crewstation concepts.

Task Summary Results:

The VECTR support task focused on three main areas of support to AVSCOM/ASRAO: development of an activity tracking data base tool; development of advanced methodologies to assess the effectiveness and aid in the synthesis of new avionic platforms and systems; and development of an avionics system/subsystem data base to complement the advanced methodologies. The activity tracking data base tool was delivered to the customer. Under customer direction, the other two are of support were subcontracted out.

Work on the development of platform/system assessment methodologies centered on a series of meetings held at the ASRAO offices at NASA-AMES. These meetings focused on three distinct areas: identifying engineering and mathematical relationships between avionics systems and integration platforms, identifying detailed operational scenarios and operational elements useful in evaluating aircraft systems, and initial definitions of the supporting avionics database.

Initial collection of data and supporting text reports on avionics systems and subsystems data base was accomplished by Marner Systems under subcontract to SAIC. Efforts in this area continued as report formats and data element definitions were revised and expanded by SAIC to support the requirements of future avionics systems and the parallel development of the advanced assessment methodologies.

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SECTION 3
SACDEF SEDATA CONTRACT
RECOMMENDATIONS AND CONCLUSIONS

In this section, we present overall SACDEF contract conclusions and recommendations. From the 41 task assignments which were worked during the five-year contract, overall resulting conclusions are discussed here. Understanding these conclusions will help to enhance AL's abilities to progress in valuable research activities. Recommendations stem from these conclusions in terms of how future continuations of AL efforts can better support the Air Force mission.

3.1   Research Advances

Through the SACDEF contract, AL achieved considerable success with research advances in many areas, including crewstation design, human performance, vision concepts, and deceptive technique effectiveness. Significant positive impacts were achieved to support the Air Force mission with advances in these areas through AL/CFHI. AL established a solid research relationship with Aeronautical Systems Center (ASC) program offices and several other laboratories, including Wright Laboratory, Avionics Directorate, Sensor Evaluation Group (WL/AARI); the Geophysics Directorate (PL/PGA); and Wright Laboratory, Hardened Materials Branch (WL/MLPJ), among others. Cooperative research efforts have allowed AL and associate laboratories to explore a broader range of research areas in an efficient manner. With such synergetic efforts, duplications of effort between labs is eliminated, and technical information transfer is strengthened.

AL's work in support of the B-1B program resulted in significant contributions to both aircraft crewstation design and operation. Activities such as the Radar Warning Receiver (RWR) Study, Automatic Map Cuing (AMC) Study, and Instrument Landing System (ILS) Study reinforced AL's expertise and role in support of the evolutionary development of strategic weapon systems. Although only recently started, AL's support of B-2 controls and displays will likewise have a significant impact as the aircraft design process is completed. Opportunities for new areas of crewstation design-related research support are likely to become available in the future as existing weapon systems are upgraded and modified in support of changing roles and missions.

AL's work with Camouflage, Concealment, and Deception (CCD) research efforts made a significant positive impact to the research community with advances in deceptive technique effectiveness understanding. AL was also involved in a joint test program, which increases the impact made to national defense programs. Additionally, multi-national cooperative efforts in CCD were conducted. This research has helped to solidify AL/CFHI's role in the CCD community.

Cooperative research efforts among the many different Air Force organizations made significant progress in concept exploration and evaluations,

resulting in better understanding of techniques supporting the DoD mission. An aggressive strategy to seek out and establish organizational alliances should be pursued to ensure an ongoing research role for AL despite inevitable funding cuts across the DoD. AL's extensive research contributions through the SACDEF contract went far beyond specific activities called out by individual task assignments. These additional publications, abstracts, and technical reports are listed in the Appendix.

3.2   Processes and Tools

The employment of automated tools and improved processes has increased AL's abilities to evolve their research simulator capabilities while still preserving the functional reliability of the systems. Structured systems engineering development methodologies provide a mechanism for early control of vital system interfaces, and the ability to carefully manage changes. Configuration Management (CM) and Quality Assurance (QA) are especially important to keeping the evolving capabilities on track. Good CM/QA processes prevent developers from reinventing the wheel, decrease test time, and help developers to see the forest in addition to the trees. Supporting a dynamic lab environment requires good communications, documentation and careful tracking, which are facilitated with CM processes. QA begins at requirements definition to ensure that development planning leads logically to scoping a sound and complete hardware/software research tool. The SACDEF tasks often present challenges of complex interrelationships. The integrity of the resulting systems have been enhanced through the application of sound systems engineering development processes.

The application of a risk management process on SACDEF tasks created a means to identify potential program problems, and take early action for mitigation. When potential risks are sought out early, consistently revisited and tracked, the program has a much greater potential to complete on schedule and within performance requirement guidelines. The risk management process requires managers and Government monitors to seek out possibilities for uncertainties, or areas that could result in a compromise of the desired product. Risk management, though often resulting in a constantly-updated list of potential program problems, should not be confused with creating a "risky" project. The value of risk management has shown to be a mechanism of creating action plans to both avoid risks when possible, and to mitigate unavoidable risks, should they occur. Programs with an active risk management program have enjoyed increased completion success.

Throughout the SACDEF contract period, processes which could contribute to increased efficiencies have been continually examined and refined. Material management was identified as a result of lessons learned in the identification, ordering, receiving, and distribution of materials. The material management process has been revised to include these lessons learned. Although many changes in procedures were incorporated, the most significant changes are reflected in inventory and accountability. Essentially, every item procured for laboratory efforts

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is formally received at the SAIC facility, inspected and inventoried by the task's Principal Investigator (PI), and all documentation, to include the DD 1149, is prepared at this time. The item and the DD 1149 are then transported to the Government, and formal turnover is completed at this time. This action results in total accountability for every item, and allows rapid inventory by AL.

The application of automated tools to define a project task structure, resource requirements, work breakdown structure, costing, and tracking the aggregate project status has assisted in the management of SACDEF tasks. Tools allow tracking of actuals versus estimates for time and cost to complete a work element. Tools produce a baseline for scoping a project or altering project direction. AL is able to maintain an increased visibility into project tracking indicators, since the automation enables ease of continued reporting. Management tools have shown their value in their ability to help managers forecast objectively, meet requirements on schedule, and rescope a project when requirements redirection occurs. The use of such management tools, which were so helpful under the task assignment arrangement of SACDEF, will be even more important and applicable under the new Delivery Order contract, SIDEF. SIDEF Delivery Orders have an even greater need to be carefully managed and controlled within cost and schedule bounds.

3.3   Maintaining Current Lab Simulators

AL has enjoyed over five years of success maintaining their laboratory crewstation simulators, with few equipment failures. The equipment and architectures have been proven reliable and effective. During SACDEF, the equipment operations and maintenance permitted day-to-day operations and special projects to be efficiently accomplished with minimal delays as a result of equipment down-time.

An advantageous commonality of software components exists across the ERS, HFDCS, and CEF models. The reusability of the aircraft dynamics, navigation systems, and weapon system models have benefited AL in that the newer crewstation simulators were able to build upon proven, working software technology. Software component reusability has enabled AL to advance their research capabilities with lower risk and lower development costs than would be possible in segregated development environments. The value of reuse and commonality of software model components were illustrated in the efficient development cycle of the CEF, which shares a number of common software models previously developed for the ERS/HFDCS. Reusability reduces time and costs associated with requirements definition, design, and implementation.

The architectures for AL simulators, including the ERS, HFDCS, CEF, and CDGS require a variety of hardware components. The ERS and HFDCS use a Concurrent central multi-processor with distributed local processing on Intel systems. The CEF uses a Concurrent central multi-processor executing models with distributed functional processing on a personal computer for the control interface,

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and Silicon Graphics running VAPS for the display interface. The Concurrent 3260 systems are common across these simulators, which facilitates software model reuse as well as hardware system maintenance. However, it should be noted that the hardware architecture was designed for the state of the art in the 1984 timeframe, and has not been significantly updated with advances in the computing industry. The Concurrent systems are now becoming relatively old, and expensive to maintain. The Intel systems are slow by today's computational standards, and their removable drives are now out of production by the manufacturer. The RasterTech displays used in the ERS and HFDCS are ill-supported since RasterTech is now out of business. While the Silicon Graphics UNIX operating system differs from other older systems in the lab, it is compatible with current industry standards. The effectiveness of continued maintainability as well as rigorous configuration management processes is diminished by the variety of hardware components, especially those which are aging relative to industry standards. A systematic trade study and analysis of hardware options will help AL retain its technical edge and abilities to progress with continued research objectives.

3.4   Team Approach

During the SACDEF contract, a close working relationship between key AL technical staff and SAIC was facilitated by physically locating the contractors in the laboratory. The concept and practice of using on-Base personnel have provided significant advantages in terms of improved communications, lower development costs, and quicker response time.

The close proximity of SAIC personnel to the key AL technical staff fostered a team approach, evidenced by the open exchange of ideas and issues concerning project improvements. Communication of system requirements, including study emphasis needs, was greatly improved due to use of on-Base personnel. With this team approach, a close interface was available which was extremely valuable in coordinating daily routine matters, and in coordinating and solving unforeseen problems. The concept of having on-Base personnel allowed AL the opportunity to review specific task status on a daily basis without the burden of calling a special meeting, and without distracting from the task efforts at hand. With on-Base personnel, user needs are more clearly communicated, and efforts are coordinated. For instance, AL worked with SAIC personnel in order to produce documented detailed operational procedures of the ERS/HFDCS. While previously, SAIC personnel were required to operate these systems, AL is now able to use a checklist for simulation operation and minor equipment trouble shooting.

AL has decreased development costs through use of on-Base contractors. In general, approximately a 15% development cost savings is realized by using on-Base personnel (as opposed to using personnel located at the contractor's place of business). This translates to about 2 additional labor-months for each year of effort, allowing task completions within tight budget constraints and requirement additions to existing tasks.

Perhaps even more important was SAIC's ability to respond to evolving requirements of SACDEF deliverables and to affect rapid coordination on existing projects and tasks. With on-Base contractor personnel, task leaders are always ready to respond to AL's needs. Evolving research needs can be fulfilled this way; though care must be given to prevent ever-changing requirements throughout the development cycle which can erode the end product's effectiveness.

A specific example of how on-Base personnel provided a significant advantage to AL was in the area of Operations and Maintenance technician support. Often ERS-type demonstrations are needed on short notice. With the O&M personnel on-Base, any demonstration could be ready in 10 minutes. Using off-site personnel, it could take 1-2 hours, depending on the type of activity the required personnel is performing at the time. If response time becomes too long, the need for the demonstration could be lost. Additionally, with on-Base personnel, the technicians are immediately available to fix hardware problems as they occur. These advantages contribute to increased productivity, understanding of user needs, and user satisfaction.

3.5   Summary

The Armstrong Laboratory has enjoyed considerable success through the SACDEF SEDATA Contract. Many significant research objectives were achieved, including several cooperative efforts with associate laboratories. Cooperative laboratory efforts have helped strengthen AL's role in research communities, and has furthered the DoD's mission in an efficient manner. Continued cooperative efforts can allow AL to achieve steady progress in innovation and research advances.

Much of AL's research is conducted using cockpit simulation devices. Established processes and automated tools have increased AL's ability to quickly and consistently generate reliable, maintainable simulation systems. Sound systems engineering development processes enable requirements to be tracked, risks to be mitigated, and desired functions to be accomplished. Management processes and tools permit tasks to be structured and tracked appropriately to ensure objective forecasting and schedule visibility. Use of automated management tracking tools will be increasingly important in future AL efforts to allow close control of delivery order progress.

AL's cockpit simulators are composed of a complex assortment of hardware and software components. Reusability of software components has significantly increased the ability to quickly create newer research simulators. Hardware components do not currently have a high degree of commonality across systems. Aging computational systems are posing potential risks for non-maintainability in the future. An analysis and trade study for computational system options will assist

in ensuring a long future of reliable systems, and open the door for increased research opportunities for AL.

The physical location of contractor personnel within AL facilities has facilitated a team approach for processes, systems engineering efforts, and study developments. Use of on-Base personnel enhanced communications and response time, while decreasing development costs. The on-Base, team approach has a positive impact to AL activities, providing dynamic and effective exchanges to increase coordination. This allows AL to more closely direct efforts and ensure that the Air Force mission is supported. Although care must be given to not permit changing requirements to detract from the ultimate product's efficacy, evolving research needs can more easily be satisfied with the team approach. On-Base support has proven successful, and should continue with AL's efforts.

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Glossary

ADMPS	Automated Defensive Mission Planning System
AF	Air Force
AFB	Air Force Base
AFHRL	Air Force Human Resources Laboratory
AFS	Avionics Flight Software
AFSATCOM	Air Force Satellite Communications System
AHMDE	Analog Helmet Mounted Display Electronics
AL	Armstrong Laboratory
AMC	Automatic Map Cuing
ANS	Artificial Neural System
ARVCS	Advanced Rotocraft Virtual Cockpit Simulator
ASD	Aeronautical Systems Division
ASGS	Automated Scenario Generation System
ASRAO	Advanced Systems Research and Analysis Office
ATAS	Advanced Target Acquisition System
ATC	Automatic Target Cuing/Cuer
AVCON	Advanced Vision Concepts
AVSCOM	Army Aviation Systems Command
AWACS	Airborne Warning and Control System
BMD	Ballistic Missile Defense
BMW	Bombardment Wing
C3I	Command, Control, Communications, and Intelligence
CABLE	Camouflage Airbase Leipheim
CCD	Camouflage, Concealment, and Deception
CDGS	Color Display Generation System
CEF	Cockpit Evaluation Facility
CFH	Human Engineering Division
CFHI	Crew Systems Integration Branch
CITS	Central Integrated Test System
CLS	Contractor Logistics Support
CONOPS	Concept of Operation
DARPA	Defense Advanced Research Projects Agency
DFAD	Digital Feature Analysis Data
DHE	Display Head Electronics
DSO	Defensive Systems Operator
DSS	Defensive Station Simulator
EC	Electronic Combat
EDU	Electronics Display Unit
EID	Emitter Identification
EIS	Electronic Imagery Systems
ERS	Engineering Research Simulator
EWWS	Electronic Warfare Weapon System
FDC	Flight Director Control
FLIR	Forward Looking Infrared
FOS	False Operating Surface
GFE	Government Furnished Equipment

Glossary (continued)

GPS	Global Positioning System
GTRI	Georgia Tech Research Institute
HAS	Hardened Aircraft Shelter
HFDCS	High Fidelity Defensive Crew Station Simulator
Hq	Headquarters
HSD	Horizontal Situation Display
I/O	Input/Output
ID	Identification
IDEF	Integrated Definition Methodology
IHADSS	Integrated Helmet And Display Site System
ILS	Instrument Landing System
ISP	Integrated Support Plan
JCCD	Joint Camouflage, Concealment, and Deception
JT&E	Joint Test and Evaluation
LAMS	Laser Atmospheric Modulation Simulator
LAN	Local Area Network
LANTIRN	Low Altitude Navigation and Targeting Infrared For Night
LSI	Lear Siegler International
LTSI	Logicon Technical Services Incorporated
MDU	Multifunction Display Unit
MFD	Multi Function Display
MIL-STD	Military Standard
ML/CBR	Multimedia Laboratory/Crew Briefing Room
MMI	Man Machine Interface
MOE	Measure of Effectiveness
MOP	Measure of Performance
MS	Milestone
MTQ	Manned Threat Quantification
NASA	National Aeronautics and Space Administration
NCA	National Command Authority
NITE	Night Imaging Threat Evaluation
NORAD	North American Air Defense Command
NVG	Night Vision Goggles
O&M	Operation and Maintenance
OBD	Order of Battle - Defensive
OCM	Optical Counter Measures
OPR	Office of Primary Responsibility
OSO	Offensive Systems Operator
P&ES	Prototyping and Evaluation System
PC	Personal Computer
PDGS	Programmable Display Generation System
PI	Principal Investigator
PST	Postload Systems Trainer
PTD	Program Test Design
RAAC	Robotic Air-To-Air Combat Vehicle

RBS	Radar Bomb Scoring
RIPI	Relocatable Target Integrated Plans/Intelligence
RN	Radar Navigator
RT	Relocatable Target
RTVS	Real Target View Simulator
RWR	Radar Warning Receiver
SAC	Strategic Air Command
SACDEF	Strategic Avionics Crew Station Design Evaluation Facility
SAIC	Science Applications International Corporation
SAM	Surface To Air Missile
SAR	Synthetic Aperture Radar
SARGE	Stroke And Raster Graphics Environment
SEDATA	Systems Engine and Technical Analysis
SFM	Strategic Force Management
SI	Sensor Integration
SIOP	Single Integrated Operational Plan
SpaDVOS	Space Based Direct View Optical System
SRL	Systems Research Laboratory
SRT	Strategic Relocatable Target
STIFF	Strategic Intelligence Future Forecast
SWAT	Subjective Workload Analysis Technique
TACAN	Tactical Air Navigation
TAP/ATVCS	Technology Assessment and Prototyping For The Advanced Tactical Virtual Cockpit Simulator
TIPS	Texture Image Processing System
TSD	Threat Situation Display
UAV	Unmanned Aerial Vehicle
VAPS	Virtual Applications Prototyping System
VCASS	Visually-Coupled Airborne Systems Simulator
VDC	Volts Direct Current
VECTR	Vertical Take-off and Landing Effectiveness In Combat/Tactical Regimes
VPD	Virtual Panoramic Display
VSD	Vertical Situation Display
VTOL	Vertical Take-off and Landing
WPAFB	Wright-Patterson Air Force Base
WST	Weapon System Trainer
YW	Training Systems Program Office

APPENDIX
SACDEF SEDATA CONTRACT
ADDITIONAL RESEARCH PUBLICATIONS, PRESENTATIONS, AND TECHNICAL REPORTS

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